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THE RELATIVE WILTING COEFFICIENTS FOR DIFFERENT PLANTS[1]

LYMAN J. BRIGGS AND H. L. SHANTZ[2]

The wide range in moisture content of different soils at the time of wilting of the plant cover appears to have been first clearly recognized by SACHS[3] in 1859. Later investigators, in extending this work, concluded that not only do soils show a wide range in moisture retentiveness, but that different groups of plants differ widely in their ability to reduce the moisture content of a given soil. Thus, the experimental work of GAIN,[4] HEINRICH,[5] HEDGCOCK,[6] and CLEMENTS[7], all indicates considerable variation in the moisture content of the soil at the time of wilting of different plants, which has been interpreted to mean that some plants are capable of reducing the moisture content of a given soil to a lower point than others; in other words, that the "non-available moisture" varies according to the kind of plant used as an indicator. In fact, this is the view which is usually presented in many of the standard works on plant physiology and plant ecology.

The difference exhibited by plants in this respect has also been considered to be an important factor in drought resistance, the additional supply of water thus made available to some plants being supposed to be sufficient to carry them through a dry period when other plants would succumb to drought. With this point of view in mind, the present writers have made an extensive series of determinations with a number of plants, including native plants from semi-arid and arid regions, to determine the variation exhibited in their ability to reduce the moisture content of the soil before permanent wilting takes place. The results of these investigations have led us to conclude that the variation exhibited by different plants is much less than has heretofore been supposed, and that it is insignificant compared with the range in moisture retentiveness exhibited by different soils.

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[1] Published with the permission of the Secretary of Agriculture.

[2] For discussion of methods and additional matter, see BRIGGS, L. J., and SHANTZ, H. L., A wax seal method for determining the lower limit of available soil moisture. BOT. GAZ. **51**:210–219. 1911.

The wilting coefficient for different plants and its indirect determination. U.S. Department Agric. Bur. Pl. Ind. Bull. 230. 1912.

The wilting coefficient and its indirect determination. BOT. GAZ. **53**:20–37. 1912.

[3] SACHS, J., Berichte über die physiologische Thätigkeit an der Versuchstation in Tharandt. Landw. Versuchs. Stat. **1**:235. 1859.

[4] GAIN, E., Action de l'eau du sol sur la vegetation. Rev. Gen. Bot. **7**:73. 1895.

[5] HEINRICH, R., Zweite Bericht über die Verhaltnisse und Wirksamkeit des Landwirtshaftlichen Versuchs-Station zu Rostock. 1894: 29.

[6] HEDGCOCK, G. G., The relation of the water content of the soil to certain plants, principally mesophytes. Bot. Surv. Neb. VI. Studies in the vegetation of the state. II. 1902: 5–79.

[7] CLEMENTS, F. E., Research methods in Ecology. 1905: 30.

The observations given in the following table embrace about 1300 observations made with plants growing in 20 different types of soil. The actual wilting coefficients as observed range from less than 1 per cent in the case of the dune sands to 17 per cent for the clay loam. In order to reduce the results of these observations to a comparable basis, the relative wilting coefficient has been determined by taking the ratio of each individual determination to the mean of all the determinations made with that soil. If the wilting coefficient for a particular plant is higher than the average, the ratio will be greater than unity. If, on the other hand, a plant is capable of reducing the moisture content below the point attained by other varieties before wilting occurs, then the ratio will be less than unity. In this way it is possible to combine all the observations made upon different soils and to determine the extent to which any particular plant is able to reduce the soil moisture content below the point reached by other plants before wilting occurs.

It will be seen from table I that the extreme values of the relative wilting coefficient for all plants upon which six or more determinations are made are represented by 0.92 for Japan rice and 1.13 for *Colocasia*. The latter plant has an extremely coarse root system, the fine fibrous roots so characteristic of the grasses being wholly absent. A plant with a root system of this kind does not reduce the water content of the soil uniformly. At the time

TABLE I

THE RELATIVE WILTING COEFFICIENTS FOR DIFFERENT VARIETIES

Plant	Variety	No.	No. of obs.	Mean ratio	Probable error of mean ratio	Probable error of single observation
Zea mays...	Boone Co. white	United States selection 119...	33	1.00	0.007	0.038
	Esperanza.....	M 66.........	16	1.06	0.013	0.052
	Minn. 13......	United States selection 133...	3	1.03	.....	.....
	Hopi.........	A 7..........	3	1.05	.....	.....
	United States selection....	165..........	4	1.00	.....	.....
	Indian flint....	....	3	1.08	.....	.....
	Northwestern dent........	....	4	1.09	.....	.....
	Laguna.......	....	4	1.05	.....	.....
	Chico.........	M 72.........	2	1.06	.....	.....
	Iowa silver mine.......	....	3	1.06	.....	.....
	Chinese.......	S.P.I. 22308 ..	3	1.03	.....	.....
Andropogon sorghum...	White durra...	S.P.I. 24997...	17	0.94	0.012	0.052
	Dwarf milo....	S.P.I. 24970...	17	0.994	0.017	0.072
	Red amber ...	S.P.I. 17543...	7	0.94	0.007	0.044
	Black amber...	Minn. 341.....	12	1.00	0.026	0.089
	Red kafir......	S.P.I 24985....	3	1.01		
	Black-hull kafir........	S.P.I. 24975...	3	1.03	.....	.....
	Dagdi durra...	S.P.I. 9856....	3	1.02	.....	.....
	Black-hull kowliang.....	G.I. 310.......	3	1.03	.....	.....
	Brown kowliang.....	S.P.I. 24993...	1	1.04	.....	.....
Chaetochloa italica.....	Kursk........	S.P.I. 22420...	27	0.954	0.008	0.040
	Common......	S.P.I. 22423...	6	0.96	0.011	0.027
	Siberian.......	S.P.I. 21076...	6	1.01	0.009	0.023
	German.......	S.P.I. 26845...	3	1.00	.....	.....
	Chaetochloa italica.......	S.P.I. 21073...	3	1.04	.....	.....
Panicum miliaceum.	Proso.........	G.I. 72.......	3	0.99	.....	.....
Triticum durum....	Kubanka......	G.I. 1440.....	593	1.00	0.0021	0.051
	Kubanka......	G.I. 1354.....	3	0.94	.....	.....
	Kubanka......	G.I. 2246.....	3	0.97	.....	.....
	Yellow gharnovka.......	S.P.I. 26008...	3	0.94	.....	.....
	Yellow gharnovka.......	G.I. 1444......	3	0.96	.....	.....
	Pelissier......	G.I. 1584.....	3	0.97	.....	.....
Triticum vulgare....	Bluestem......	Minn. 169.....	28	0.96	0.0066	0.035
	Turkey red....	G.I. 1558.....	11	0.99	0.0116	0.038
	Fretes........	S.P.I. 19239...	3	0.94	.....	.....
	Power's fife....	G.I. 3025......	3	0.95	.....	.....

TABLE I—*Continued*

Plant	Variety	No.	No. of obs.	Mean ratio	Probable error of mean ratio	Probable error of single observation
Triticum dicoccum	Spring emmer	S.P.I. 19907	3	1.07	......	......
Avena sativa	Kherson	G.I. 459	15	1.03	0.0149	0.058
	Swedish select	S.P.I. 24877	13	0.984	0.009	0.033
	Canadian	S.P.I. 12880	3	0.96	......	......
	75 day	G.I. 337	3	1.02	......	......
	60 day	G.I. 639	3	1.04	......	......
	Big 4	G.I. 558	3	1.03	......	......
	Burt	S.P.I. 24670	3	0.93	......	......
	Red rust proof	G.I. 458	3	0.92	......	......
Hordeum distichon	White smyrna	G.I. 195	3	0.94	......	......
	Hannchen	G.I. 531	18	0.98	0.011	0.047
	Unknown	....	16	0.98	0.013	0.034
Hordeum vulgare	Beldi	G.I. 190	14	0.97	0.013	0.054
	Telli	G.I. 194	3	0.92	......	......
	Mariut	G.I. 261	3	0.95	......	......
	Oderbrucker	S.P.I. 26105	2	0.92	......	......
	Hull-less	S.P.I. 12709	1	0.91	......	......
Secale cereale	Giant winter rye	....	19	0.94	0.011	0.049
Oryza sativa	Japan	G.I. 1642	15	0.92	0.014	0.054
	Carolina golden	G.I. 1645	3	0.96	......	......
	Honduras	G.I. 1643	3	1.03	......	......
Gramineae	Bromus inermis	....	33	0.94	0.005	0.028
	Agropyron Smithii	....	11	1.03	0.013	0.043
	Agropyron tenerum	....	15	0.99	0.013	0.052
	Agropyron cristatum	....	6	0.96	0.013	0.032
	Elymus canadensis	....	3	1.00	......	......
	Stipa Vaseyi	....	3	0.99	......	......
	Sitanion hystrix	....	3	0.97	......	......
	Aristida longiseta	....	2	1.00	......	......
	Bouteloua oligostachya	....	1	1.01	......	......
Leguminosae	Medicago sativa	S.P.I. 25695	33	0.98	0.006	0.035
	Vicia villosa	S.P.I. 25935	17	1.04	0.013	0.053
	Vicia faba	S.P.I. 15428	23	1.02	0.016	0.078
	Pisum arvense	S.P.I. 19389	28	1.05	0.012	0.064
	Melilotus alba	S.P.I. 21216	8	1.03	0.012	0.033
	Vicia fulgens	S.P.I. 21502	6	0.93	......	......
	Vicia atropurpurea	S.P.I. 18132	3	1.05	......	......
	Vicia ervilia	S.P.I. 16137	3	0.92	......	......
	Cicer arietinum	S.P.I. 24322	3	0.93	......	......
	Vigna unguiculata	S.P.I. 26497	3	0.98	......	......
	Trifolium pratense	....	5	1.04	......	......

TABLE I—*Continued*

Plant	Variety	No.	No. of obs.	Mean ratio	Probable error of mean ratio	Probable error of single observation
Leguminosae	Onobrychis viciaefolia. . .	S.P.I. 24931. . .	3	1.00	. . . . . .	. . . . . .
	Lupinus pusillus	. . . .	2	0.97	. . . . . .	. . . . . .
Cucurbitaceae.	Cucurbita pepo	. . . .	15	1.01	0.018	0.073
	Cucumis sativa.	. . . .	1	0.90	. . . . . .	. . . . . .
	Cucumis melo. .	. . . .	1	1.04	. . . . . .	. . . . . .
Lycopersicon esculentum	Livingston.	. . . .	17	1.05	0.011	0.043
	Stone.	. . . .	3	1.08	. . . . . .	. . . . . .
Colocasia. . . .	. . . .	S.P.I. 21190. . .	19	1.13	0.015	0.059
Mesophytes. .	Ipomoea purpurea.	. . . .	3	1.11	. . . . . .	. . . . . .
	Plantago lanceolata.	. . . .	2	1.06	. . . . . .	. . . . . .
	Citrus limonum	. . . .	1	0.96	. . . . . .	. . . . . .
	Abutilon striatum.	. . . .	2	0.91	. . . . . .	. . . . . .
	Gossypium hirsutum.	. . . .	2	1.05	. . . . . .	. . . . . .
	Coleus.	. . . .	5	0.99	. . . . . .	. . . . . .
	Lactuca sativa. .	. . . .	3	1.11		
	Solanum tuberosum.	. . . .	3	1.06	. . . . . .	. . . . . .
	Fagopyrum vulgare.	. . . .	1	1.05	. . . . . .	. . . . . .
	Beta vulgaris. .	. . . .	3	1.06	. . . . . .	. . . . . .
	Linum usitatissimum.	. . . .	2	0.99	. . . . . .	. . . . . .
	Brassica napus	. . . .	3	0.94	. . . . . .	. . . . . .
	Amaranthus retroflexus. . .	. . . .	5	1.01	. . . . . .	. . . . . .
Xerophytes. .	Grindelia squarrosa.	. . . .	4	1.08	. . . . . .	. . . . . .
	Vernonia marginata.	. . . .	3	1.04	. . . . . .	. . . . . .
	Artemisia gnaphalodes. . . .	. . . .	6	1.06	. . . . . .	. . . . . .
	Pachyphytum aduncum. . . .	. . . .	1	1.03	. . . . . .	. . . . . .
	Echeveria pubescens	. . . .	1	1.10	. . . . . .	. . . . . .
	Nopalea coccinelifera	. . . .	1	1.03	. . . . . .	. . . . . .
Hydrophytes.	Ranunculus septentrionalis. .	. . . .	2	0.98	. . . . . .	. . . . . .
	Juncus balticus	. . . .	1	1.07	. . . . . .	. . . . . .
	Nasturtium. . . .	. . . .	3	1.03	. . . . . .	. . . . . .
	Isoetes saccharata.	. . . .	2	1.33	. . . . . .	. . . . . .
Weighted mean.	. . . .	. . . .	. .	1.00	. . . . . .	0.054

the plant wilts, the soil farthest from the roots contains more water than the soil immediately surrounding the roots. Consequently, the determination of the moisture content of the whole soil mass at the time of wilting gives too high a value for the wilting coefficient. Aside from the *Colocasia*, a variety of corn gave the highest relative wilting coefficient, namely, 1.06. The several varieties of corn differed slightly, the lowest value being given by Boone County white, a variety native to wet regions. Mexican and Indian varieties, natives of dry regions, gave no evidence of being able to reduce the soil moisture content lower than other varieties. Only slight differences were found in the relative wilting coefficient in the different varieties of sorghum, a crop extensively grown in semi-arid regions. The relative wilting coefficient of two of the varieties tested was 0.94, indicating that these varieties were capable of reducing the moisture content of the soil somewhat below the point reached by corn at the time of wilting. The difference in the wilting coefficient of the varieties of the small-grain crops, millet, wheat, oats, and barley, is slight, the extreme range for the four crops being from 0.95 to 1.03. The value of the wilting coefficient obtained for rye was 0.94 and for Japan rice 0.92. The low value found for the latter plant is of special interest in view of the fact that it is generally considered necessary to keep rice fields flooded during the greater part of the growing season.

The different grasses, most of which are natives of the Great Plains of the United States, gave ratios differing only slightly from each other and from the small grains. Most of the legumes, on the other hand, and certain of the coarse-rooted plants of the Great Plains, gave slightly higher values for the relative wilting coefficient. These high values, we believe, are to be attributed to imperfect root distribution rather than to any inherent inability of these plants to reduce the soil moisture content to the point reached by other plants.

The miscellaneous plants upon which only a few determinations have been made are grouped in the last part of the table as hydrophytes, mesophytes, and xerophytes. The water plants gave a mean wilting coefficient slightly higher than the other groups, due to the presence in this group of *Isoetes*, submerged plants of which were taken from the water and grown in the air without being permitted to develop new leaves. This plant also had a poor root distribution. If we except *Isoetes*, the other hydrophytes give a mean wilting coefficient identical with that of the mesophytes. The xerophytes tested gave a mean ratio intermediate between the hydrophytes and mesophytes. This would indicate that plants native to dry regions are unable to reduce the water content of the soil to a lower point than is reached by other plants at the time of wilting.

TABLE II

THE RELATIVE WILTING COEFFICIENT FOR DIFFERENT PLANTS

PLANT	NO. OF OBSERVATIONS	MEAN RATIO	PROBABLE ERROR	
			Of mean ratio	Of single ratio
Zea	75	1.03	0.003	0.042
Andropogon	66	0.98	0.008	0.062
Chaetochloa italica	48	0.97	0.006	0.035
Triticum	653	0.994	0.002	0.049
Avena	46	0.995	0.007	0.047
Hordeum	60	0.97	0.006	0.047
Secale	19	0.94	0.011	0.049
Oryza	21	0.94	0.012	0.054
Gramineae	77	0.97	0.005	0.040
Leguminosae	138	1.01	0.005	0.059
Cucurbitaceae	17	0.99	0.016	0.068
Lycopersicon	20	1.06	0.009	0.040
Colocasia	19	1.13	0.005	0.066
Hydrophytes	8	1.10	0.037	0.105
Mesophytes	35	1.02	0.010	0.058
Xerophytes	16	1.06	0.008	0.032
Total number of observations	1,318	.....	.....	.....
Weighted mean	.....	1.00	.....	.....

The results of the different crops have been summarized in table II without reference to varieties. Reference to the table will show that only slight differences exist among the various crops in their ability to reduce the soil moisture content before wilting occurs. Sorghum, millet, wheat, oats, barley, and the grasses are practically the same. Rye and rice appear to be a little lower than the mean, corn and the legumes slightly higher.

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